Doing Different Things or Doing It Differently?

Rice Intensification Practices in 13 States of India

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Can the System of Rice Intensification be the answer to meet the country's future rice demand? A macro-level study covering 13 major rice-growing states indicates that fields with SRI have a higher average yield compared to non-SRI fields. Out of the four core SRI components typically recommended, 41% adopted one component, 39% adopted two to three components, and only 20% adopted all the components. Full adopters recorded the highest yield increase (31%), but all adopters had yields higher than those that used conventional practices. They also had higher gross margins and lower production costs compared to non-SRI fields. Though the rice yield of the country can significantly increase under SRI and modified SRI practices, there are major constraints that have to be tackled before this can be achieved.

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1 Introduction

The System of Rice Intensification (SRI), an improved cultivation practice, is claimed to greatly enhance yield and substantially reduce water and other input use in smallholder farming (Uphoff 2003). Since being first implemented in Madagascar in the second half of the 1990s, it has reportedly spread to nearly 50 countries in Asia, Africa, and South America. Although reliable data on actual levels of adoption and its impact are not available for India, the information that is accessible has attracted the attention of policymakers and planners, and efforts have been made to promote SRI in different states. Claims of actual adoption levels and yield increase are still being debated in different circles, including among researchers and extension officials. There are questions about profitability and field trials producing inconsistent results (Glover 2011), as well as assertions that SRI productivity claims go beyond the physiological yield potential of rice (Dobermann 2004).

However, the issue facing Indian agriculture is not whether SRI should be adopted, but how it should be adopted across different regions. The available data confirms that SRI has increased yield and reduced the use of water in select locations (Latif et al 2009, 2005; Thakur et al 2009; Kumar Sinha and Talati 2007; Sita Devi and Ponnarasi 2009; Barah 2009; Karunakaran et al 2010; Adusumilli and Bhagya Laxmi 2011, Glover 2011). What is missing is an insight into actual levels of adoption in different regions of the country, and whether adoption can be encouraged by promoting the core components of SRI as a package or only some of the components with modifications. This paper uses data from 13 rice-growing states in India to address (i) the yield, income and cost advantage of SRI over non-SRI practices; (ii) the level of adoption of different components of SRI by farmers; (iii) the drivers of SRI adoption; and (iv) the constraints faced by farmers in the adoption of SRI.

2 Study Area and Sample

The study was conducted during 2010-11 in 13 states and covered 2,234 sample farmers with SRI and non-SRI fields in the southern region (Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala), western region (Gujarat, Rajasthan, and Maharashtra), eastern region (Odisha, Chhattisgarh, Uttar Pradesh, and West Bengal), central region (Madhya Pradesh), and north-eastern region (Assam).[1] Data related to the adoption of SRI core components, costs, returns, and constraints were collected through interviews with farmers using pretested questionnaires. In addition, extension officials, 70 non-governmental organisations (NGOs), 60 scientists associated with SRI programmes, and 120 key farmers were contacted for getting an overall picture of SRI practices in different localities.

Table 1: Categorisation of SRI Core Component Adoption Levels

No	Concept of Core Components	Conventional Method	Criteria for Core Components of SRI Adoption		
			Full Adopter (Score=3)	Partial Adopter (Score=2)	Low Adopter (Score=1)
1	Number of seedlings	>4	1	2-3	>3
2	Younger seedlings (days)	35-45	<15	15-20	>20
3	Square planting (cm)	15x10 or 15x15	25x25	Row planting >20	Row planting 15x10 or 20x10
4	Cono-weeding	Manual	>2 times	1 time	Nil

SRI involves four core components – using a single seedling per hill, transplanting seedlings at a young age of less than 15 days, square planting (25 cm × 25 cm spacing), and cono-weeding (using a small implement drawn manually along the rows to remove weeds).[2] To gauge the level of adoption of these core components, farm samples were classified on the basis of the degree to which they practised them. As shown in Table 1, depending on the degree of adoption, 1 to 3 points were given to each component, and a total score was arrived at by adding up the points for all components. Farm samples were classified as full adopters if the sum was 12 and low adopters if the sum was six and below. Scores between seven and 11 were categorised as partial adopters. Further, using the levels of adoption of SRI, the factors influencing this (such as socio-economic characteristics, soil types, and irrigation sources) were examined using a multinomial logistic regression (Appendix 1, p 57).

Table 2: Differences in Yield, Cost and Gross Margin between SRI and Non-SRI Fields

Region and State	Yield (q/ha)			Gross margin (Rs/ha)			Cost (Rs/q)		
	Non-SRI Fields	Difference (SRI- non-SRI)		Non-SRI Fields	Difference (SRI- non-SRI)		Non-SRI Fields	Difference (SRI- non-SRI)	
		Total	%		Total	%		Total	%
Southern region									
1 Andhra Pradesh	56.8	13.0	22.9	54,490	10,094	19	560	-146	-26
2 Karnataka	56.7	14.1	24.8	56,277	12,885	23	370	56	15
3 Kerala	47.1	6.4	13.6	51,613	7,044	14	857	-244	-28
4 Tamil Nadu	45.5	6.8	14.9	41,879	5,786	14	675	-223	-33
Average	51.0	9.2	18.0	49,552	8,290	17	617	-168	-27
Western region									
5 Gujarat	18.7	10.0	53.6	17,274	8,973	52	757	-234	-31
6 Maharashtra	27.9	7.5	26.9	26,904	4,266	16	527	-253	-48
7 Rajasthan	20.9	2.7	12.9	41,145	5,327	13	2068	-201	-10
Average	25.6	7.3	28.5	27,597	6,585	24	715	-220	-31
Eastern region									
8 Chhattisgarh	48.7	11.9	24.5	53,451	1,257	2	581	-167	-29
9 Odisha	36.2	12.0	33.1	33,929	12,111	36	669	-151	-23
10 Uttar Pradesh	54.5	8.5	15.5	53,655	8,334	16	655	-41	-6
11 West Bengal	36.0	5.9	16.5	32,885	5,400	16	507	-14	-3
Average	40.9	9.0	22.0	38,446	7,474	19	585	-71	-12
Central region									
12 Madhya Pradesh	19.3	10.0	51.9	12,530	11,184	89	430	-56	-13
North-eastern region									
13 Assam	34.1	4.1	12.0	32,188	3,504	11	674	-380	-56
All India	37.9	8.5	22.4	37,845	6,971	18	621	-178	-29

Source: Authors' estimates based on sample survey.

3 Analysis of SRI Yield, Income and Adoption Levels

3.1 Yield, Income and Cost Difference between SRI and Non-SRI Fields

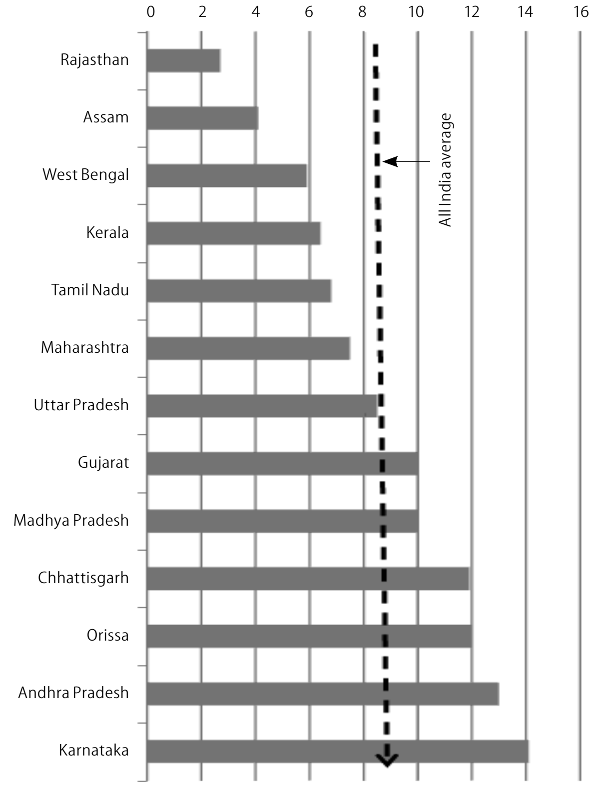
Table 2 shows a comparison of SRI and non-SRI fields among the sample farmers. The average area of non-SRI fields (0.94 hectare) is slightly larger than SRI fields (0.72 ha). This can be explained by the fact that small and marginal farmers often adopt SRI in their total area, while large farmers adopt it only on parcels of about 1 ha. The t-test results on farm size categories confirmed that there is no significant difference in SRI yield, particularly between small and large farms. However these (small and large farms) had significantly different yields compared to marginal farms in the south and western regions (Appendix 2, p 58). The reason might be that in these regions, the average area of the small and large farmers under SRI and non-SRI is more or less same with the same level of cultivation practices compared to marginal farms which had adopted a comparatively higher level of core SRI components resulting in higher yields possibly due to greater management inputs.

Marginal farmers with small areas had comparatively higher scores of SRI component adoption, resulting in higher yields.

Generally, SRI fields have significantly higher yields, but the patterns are different across states. The average yield in SRI parcels in all states is 8.5 quintals per hectare (0.85 tonnes/ha), which is 22% higher than in non-SRI fields. Madhya Pradesh, Gujarat, and Odisha have significantly higher yields in SRI parcels in percentage terms (52%, 54% and 33% respectively), but they have some of the lowest yields among non-SRI fields. Maharashtra, Chhattisgarh, Andhra Pradesh, and Karnataka have the next highest yield increments with SRI – 27%, 24%, 23% and 25% respectively. Among the other major rice-growing states, only Rajasthan and Assam have low absolute yield increases, but they still recorded a more than 12% increment compared to non-SRI parcels. Kerala, Tamil Nadu and West Bengal have recorded only moderate yield increases. Overall, only six states have experienced yield increases above the national average due to SRI (Figure 1, p 53).

The average gross margin (gross income minus variable costs) due to SRI ranged from Rs 6,971/ha in the central region to Rs 3,504 in the north-east. Assam, Chhattisgarh, Maharashtra, and Rajasthan have low incomes, possibly due to high operating costs. The cost of production (COP) per quintal of rice indicates the real profitability of cultivation. Overall, the COP of SRI over non-SRI was lower by Rs 178/q. The western and southern regions have a comparatively lower COP over other regions.[3] Rajasthan has the highest COP due to the cultivation of basmati rice varieties with higher input costs and low yields (Palanisami and Karunakaran 2012).

Figure 1: SRI Yield Increases in Different States (Q/ha)



3.2 Yield Differences by Different Adoption Levels

The adoption of a number of SRI components alone does not exactly indicate the level of SRI adoption as some farmers may strictly follow the recommendations, while others may deviate from them. To get a comprehensive picture of actual SRI adoption, farmers were grouped as full adopters, partial adopters and low adopters using the scoring method explained in Section 2.

First, not all farmers adopted all four core SRI components. The adoption of a combination of two to three components was mostly observed in all the regions.[4] The low adopters were 41% of all adopters, while 39% and 20% were partial and full adopters respectively. The adoption level varied from region to region, with the north-east having only low adopters and the eastern region having mostly partial adopters (Table 3, p 54).

Second, full adopters of SRI recorded the highest difference in yield between SRI and normal practices (31%), followed by partial (25%) and low adopters (15%). This indicates that the adoption of different SRI components has a significant bearing on yield increase. The yield difference varied across regions, being lowest in the north-east and highest in the central region (Figure 2).

As expected, the percentage of full adopters was high in regions where the average yield level went up, and there was a corresponding decrease in partial and low adopters, confirming that full adoption results in higher yields (Figures 2 and 3).

3.3 Yield Difference by Core SRI Components

The yield under different SRI components over non-SRI parcels varied across regions. For example, the yield difference for all the four SRI components as well as for a single SRI component (C3, or square planting) was 11.2 q/ha (Table 4, p 54). Much of the yield difference was realised by partial adopters in the southern region, low adopters in the north-east region, and full adopters in other regions (Table 5, p 54). The maximum yield difference of 17.5 q/ha was observed for a combination of C1, C2, and C4 (young seedling, single seedling and cono-weeding). Overall, mixed responses of yield for different combinations of the SRI components were noticed. It is interesting to note that about 31% (or 691 of 2,234) of the farmers who deviated in all the four SRI components realised a yield increase of 6.6 q/ha, indicating that any improvement from existing practices will enhance the rice yield. The overall increase in COP due to SRI adoption varied across combinations of the SRI components, though the cost was lower in most cases.

3.4 Transaction Cost and SRI Adoption

Transaction cost refers to the costs associated with the efforts made by farmers to mobilise resources such as labour in time for operations, nursery management, release of water, and cono-weeding, which are not included in cost calculations.

Figure 3: Yield Differences at Different Levels of SRI Adoption

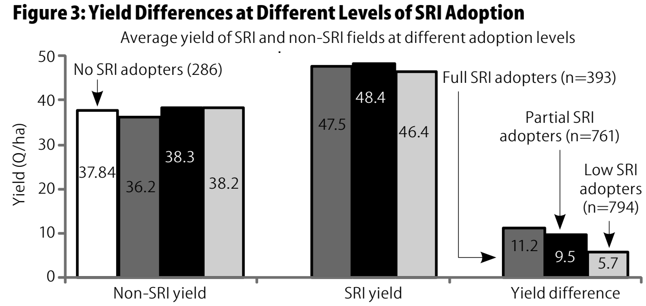
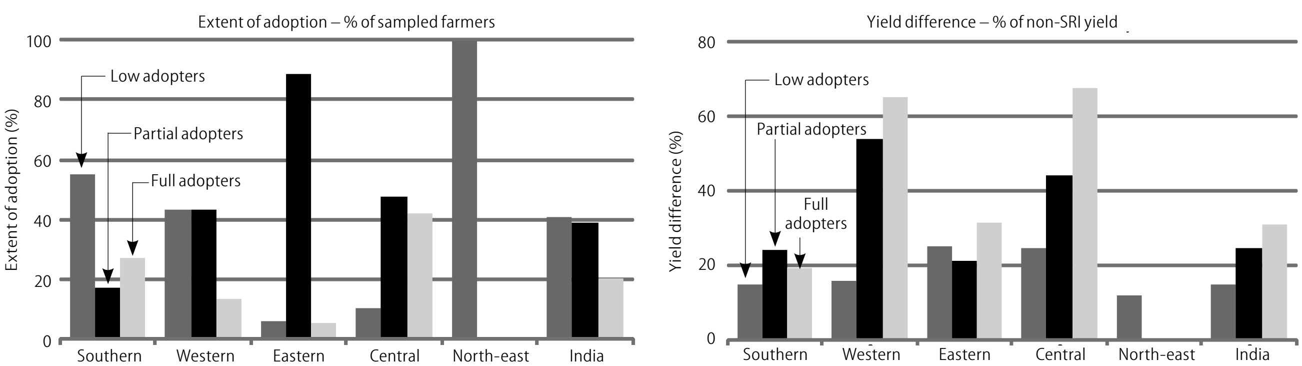


Figure 2: Adoption Levels and Yield Increases of SRI in Different Regions



Most of the farmers said that mobilising these "quality inputs" consumed extra time and money. Hence, the transaction cost was worked out using imputed values for the time and money spent by farmers (Table 6). The calculated cost was cross-checked with farmers in several locations. The transaction cost accounts for an additional 1.5% of the total operation cost with one SRI component (low adoption), 2% with two to three components (partial adoption), and 2.5% with all components (full adoption).[5] Though it is argued that a high transaction cost constrains SRI adoption, the results from the study could not confirm this because it is difficult to quantify the "quality of efforts" made by farmers in mobilising resources such as skilled labourers for land levelling, transplanting young and single seedlings, cono-weeding, and maintaining a thin layer (2.5 cm depth) of water in the fields.[6]

Table 3: Adoption Levels of SRI in Different Regions

Region	% of Farmers at Different Adoption Levels			Yield in Non-SRI Parcels at Different Adoption Levels (q/ha)			Yield Increase in SRI Parcels over Non-SRI Yields at Different Adoption Levels (%)		
	Low	Partial	Full	Low	Partial	Full	Low	Partial	Full
Southern	55	17	27	45.5	54.4	51.6	15.2	24.3	19.5
Western	43	43	14	22.7	17.6	19.3	15.8	53.9	65.0
Eastern	6	89	6	46.3	40.6	39.7	25.4	21.2	31.4
Central	10	48	42	15.4	21.6	17.8	24.7	44.1	68.0
North-east	100			34.1			12.0		
All India	41	39	20	38.2	38.3	36.2	15.0	24.8	30.9

Table 4: Differences in Yield, Cost, Gross Value of Outputs under SRI Components

Fully Adopted Components	Sample Size	Differences Between Average of SRI and Non-SRI Fields		
		Yield (q/ha)	Cost of Production (Rs/q)	Gross Value of Output (Rs/ha)
C1, C2, C3, C4	393	11.2	-179	9,592
C2, C3, C4	76	8.7	-110	8,027
C1, C3, C4	47	9.6	-119	11,252
C1, C2, C4	35	17.5	-18	8,478
C1, C2, C3	93	13.1	-190	10,384
C3, C4	185	6.7	-7	6,064
C2, C4	10	10.3	87	5,051
C2, C3	38	11.0	-91	12,270
C1, C4	14	8.7	-82	9,874
C1, C3	29	12.8	-93	11,459
C1, C2	97	10.4	-213	-1,104
C4	20	9.6	21	14,108
C3	41	7.2	-14	7,178
C2	41	9.2	-310	14,631
C1	138	6.1	-190	3,869
Not adopted all components	691	5.5	-294	4,695

C1: young seedling; C2: single seedling; C3: square planting; C4: cono-weeding.
Source: Authors' estimates based on sample survey.

Table 5: Yield Difference under SRI Components and Adoption Levels

Fully Adopted Components	Yield Difference of SRI and Non-SRI Fields across Regions and Adoption Levels (q/ha)												
	Southern Region			West			East			Central			North-east
	Low	Partial	Full	Low	Partial	Full	Low	Partial	Full	Low	Partial	Full	Low
C1, C2, C3, C4			10.1			12.6			12.5			12.1	
C2, C3, C4		8.4			8.1			8.8			9.9		
C1, C3, C4		13.5			6.4			8.8			0.0		
C1, C2, C4		10.7			4.9			12.4			19.7		
C1, C2, C3		15.5			13.1			13.9			10.2		
C3, C4		17.3						6.4					
C2, C4		10.3			9.9								
C2, C3		12.2			10.2			10.7					
C1, C4		11.4						9.9			2.5		
C1, C3		13.9						12.2					
C1, C2		4.2			2.5			12.8			6.6		
C4		15.2		0.0							-0.3		
C3	-5.0	20.0			5.0			7.2			7.2		
C2					4.0			8.4		7.8	17.5		
C1	7.1			22.5			6.4	1.6			5.0		
Not adopted all components	6.9	11.7		3.1			13.0	4.5		2.0	4.8		4.1

3.5 Drivers of Adoption Levels using Multinomial Logistic Regression

A multinomial logit model was fitted separately for the central, eastern, southern and western regions using the SPSS software package. Age, education levels, farming experience of the head of households, farm size, irrigation sources, and soil types were tested for their influence on yield among the different adoption levels in each state. The variables that were significant were included in the multinomial regression. Since all farmers in the northern region are partial adopters, the analysis was not done for this region. The dependent variable was level of adoption, and independent variables were farming experience, total family labour, soil types, and source of irrigation. The model Chi-square values for all the four regions were statistically significant, implying that there is a significant relationship between adoption levels and the set of independent variables. The overall percentages of accuracy of the predictions for the above regions were 88%, 85%, 81% and 84% respectively.

Table 6: Transaction Cost for Adopting SRI Core Components

Fully Adopted Components	Southern Region	Western Region	Eastern Region	Central Region	North-eastern Region	All India
C1, C2, C3, C4	653		640	710		655
C2, C3, C4	610		495			564
C1, C2, C4	613		630	680		630
C1, C2, C3	600	580	650	670		621
C3, C4	610					610
C2, C4	550	630	475	360		513
C2, C3	540		410			508
C1, C3	570	610	517	560	640	569
C1, C2	425	560	437	560	420	463
C4	408		435			417
C3	415	320	370	218	230	336
C2	260	460	462	540	230	386
C1	400	235	279		340	322
Not adopted all components	280	190	230	310	200	250

C1: young seedling; C2: single seedling; C3: square planting; C4: cono-weeding.

Likelihood ratio tests and parameter estimates were done to identify the statistically significant predictor variables. The likelihood ratio test indicated the contribution of the variable to the overall relationship between the dependent variable and the independent variables. The results in Table 7 (p 55) show that soil type and source of irrigation are important determinants of the adoption of SRI practices in all the four regions, while total family labour is also an important determinant in the eastern and southern regions. In the western region, experience in farming is an important determinant of adoption. The parameter estimates provide an in-depth analysis focusing on the role of each explanatory variable in differentiating between the groups specified by the dependent variable, that is, adoption levels.

In the eastern region, the variables that had a statistically significant relationship differentiated partial adopters from low adopters. They were total family labour, black or clay soil, and groundwater irrigation, while total family labour was the variable differentiating full adopters from low adopters. The odds ratio corresponding to total family labour (-0.007) indicates that an increase in total family labour (days) makes a farmer about 1% less likely to choose partial adoption of SRI over low adoption. Similarly, the odds ratio for black soil and clay soil signifies that black soil decreases the likelihood that a farmer will choose partial adoption over low adoption by 83%, while the corresponding figure for clay soil is 97%. This shows that these soil types are not suitable for partial adoption in the eastern region. The odds ratio for groundwater irrigation is 0.166, implying that groundwater as a source of irrigation decreases the probability of partial adoption over low adoption by 83%. For full adopters, total family labour was the significant variable with an odds ratios of 0.996. Similar conclusions can be drawn for other regions as well. The odds ratio for farming experience of partial adopters in the western region is 0.904, implying that an increase in farming experience will decrease the probability of choosing partial adoption over low adoption by 10%.

Table 7: Factors Influencing Adoption Levels of SRI Components in Different Regions

Regions	Eastern Region		Central Region		Southern Region		Western Region
Variables	Partial Adopter	Full Adopter	Partial Adopter	Full Adopter	Partial Adopter	Full Adopter	Partial Adopter
Constant	4.776	1.470	2.092	-15.548	25.206	14.705	-23.866
Farming experience (years)	0.014	0.041	-.038	-.070	.032	.040	-.101***
Total Family labour (days/yr)	-.007***	-0.004**	.016	.011	-.003	-.006**	-.004
Black soil	-1.766**	-0.562	21.473	22.717	1.650	.862	21.723***
Clay soil	-3.239***	0.064	–	–	-10.123	-12.279	–
Red Soil	–	–	18.040	35.752	-9.277	-8.878	–
Clay loam soil	0.827	0.307	19.052	36.134	-9.638	-10.935	27.109
Surface irrigation	0.495	-.417	-2.024	-3.348	-11.633	-1.212	4.059*
Groundwater irrigation	-1.795**	-1.123	15.732	-1.186*	-9.915	-.032	4.880***
Conjunctive irrigation	0.076	1.310	–	–	-11.576	-1.577	1.762

Low adopter is reference category; *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level.

Thus the results of the analysis point out the key variables influencing levels of adoption of SRI components. Surface and conjunctive irrigation systems are more important for full adoption of SRI components than for partial or low adoption. In general, moving from low to partial and full adoption levels is influenced by different variables and the same variable does not influence adoption at all levels. This conveys to policymakers and those promoting SRI adoption that the variables that are important at each level of adoption should be examined and issues addressed accordingly.

3.6 Suggested SRI Components and Soil Types by States

The SRI components that give higher yields in different states can be recommended, provided that the states concerned are interested in promoting them (Table 8, p 56). The results reveal that sandy loam or clay loam with groundwater or a conjunctive irrigation system produced higher SRI yields. A geographic information system (GIS) mapping of these locations will be useful for possible SRI/modified SRI concentration.

3.7 Constraints to the Adoption of SRI Components

The constraints analysis reveals that though the planting of young, single seedlings is important to realising additional yield in SRI, farmers refrained from adopting this practice to avoid the risk of losing seedlings because of waterlogging, scarcity of water due to intermittent power supply (in groundwater irrigated situations), and poor land terrain (slope) causing waterlogging and drainage problems. One-fourth of the farmers reported lack of knowledge of SRI practices. Labour problems were reported by half the SRI farmers, particularly for cono-weeding on some hard soils. About one-third of the farmers cited the non-availability of suitable markers as a major reason for deviating from square planting (Palanisami and Karunakaran 2012).

Views of Scientists

Most of the scientists interviewed were from universities, research stations, and Krishi Vignan Kendras (KVKs). Though many had no specific training in SRI, they all knew about SRI practices through lectures, literature, CDs and the internet. According to them, the major constraints to large-scale adoption of SRI were the following:

(a) The labourers who transplant seedlings are not trained in SRI methods. It is their availability that determines whether transplanting is done at the two-leaf stage (8-10 days) or later.

(b) The row-to-row and plant-to-plant distance of 25 cm (square planting) is not properly maintained. It usually varies between 18 cm and 20 cm. Labourers often use their own judgment of distance while transplanting and do not use markers. In some cases, their haste to finish the job results in more than one seedling being transplanted per hill.

(c) Even though many state governments promote SRI as a means of increasing rice yield, markers and cono-weeders are not available to farmers at affordable prices.

Views of Agricultural Extension Officials

Despite SRI's advantages, many locations are not suitable for it either due to soil or water problems. A paucity of labour and the cumbersome processes of cono-weeding and square planting also discourage farmers from fully adopting SRI. The non-adoption of SRI components may even have resulted in a reduction in yield in some cases. Obtaining organic manure and distributing it to small and marginal farmers is a difficult task and this is seldom done. Not adopting all the recommended practices leads to SRI not giving expected yields and farmers losing interest in it. Though subsidies for SRI are available in a few schemes, it is difficult to locate all SRI farmers to provide them with these.

3.8 Conclusions and Recommendations

The average yield increase of SRI parcels over non-SRI ones is about 22%, though it varies across regions. The southern region, which dominates rice production in the country, reports an 18% increase in average yield, but absolute increments in Andhra Pradesh and Karnataka are as high as any other region. The western and central regions, which have low rice yields in non-SRI parcels, have 29% and 52% higher yields respectively in SRI parcels. The eastern region has a 22% higher yield in SRI parcels. Thus, it is clear that SRI has a significant yield benefit in most regions.

At present, there is mostly low adoption (41%) and partial adoption (39%) of SRI in all the regions. However, the yield increase under full adoption is significantly higher (31%) than the yield increase under partial (25%) or low adoption (15%). SRI/modified SRI practices have a higher gross margin (Rs 7,000/ha) and lower production cost (Rs 178/q) compared to non-SRI parcels. The modifications in SRI practices are mainly due to problems related to surface and groundwater supply, soil types, droughts/floods, crop seasons (kharif/rabi), and the availability of skilled labour. The modifications primarily include two young seedlings (instead of one), 15 to 18-day seedlings (instead of 15-day ones), machine transplanting (instead of hand transplanting), and one to two cono-weedings (instead of three). Water management was not observed in most of the cases.

Table 8: Suggested SRI Components and Soil Types

No	States	SRI Components	Soil Type
1	Andhra Pradesh	C1, C2, C4	Sandy loam
2	Karnataka	C1, C2, C4	Black
3	Kerala	C1, C2, C3, C4	Red
4	Tamil Nadu	C1, C2, C3, C4	Clay
5	Gujarat	C1, C2, C3	Black
6	Rajasthan	C3	Black
7	Maharashtra	C1	Clay loam
8	Odisha	C2	Clay loam
9	Chhattisgarh	C1, C2, C4	Black
10	Uttar Pradesh	C1, C3	Clay loam
11	West Bengal	C2, C3, C4	Sandy loam
12	Madhya Pradesh	C1, C2, C4	Clay loam
13	Assam	C1	Sandy loam

C1: young seedling; C2: single seedling; C3: square planting; C4: cono-weeding; though irrigation sources (such as surface or groundwater) are important for better SRI adoption, it varies from location to location due to poor water control and no inference about the suitability of a particular irrigation source for SRI adoption could be made.

The major constraints in the adoption of SRI/modified SRI practices are a lack of skilled manpower available in time for planting operations, poor water control in the fields, and unsuitable soils. Farmers felt that the transaction (managerial) cost, though insignificant, also constrains full adoption of SRI. Hence, interventions are necessary to address these constraints.

The key message is that there is an increase in yield compared to conventional practices whether it is SRI or modified SRI. The issue is deciding where and how SRI practices should be promoted.

Key Recommendations

Given the current area under rice in the country is about 42 million ha, the difference in yield due to SRI should make it possible to produce an additional 30 million tonnes of rice, with the eastern region accounting for about 56% of the increase, followed by the southern region (27%).[7] So a region-specific focus can be given to efforts to boost rice production using SRI/modified SRI practices. Towards this, we suggest the following measures.

(1) Selective SRI components: As most farmers are low and partial adopters, it would be sensible to focus on the specific components of SRI that suit particular regions. The focus could be on those SRI components that have contributed to a yield increase or cost reduction in each region or state. It will be easy to develop packages for specific SRI components for different

states and regions. This will minimise the transaction cost of farmers by minimising the time and money spent on other components that do not directly contribute to an increase in yield.

(2) Doing it differently: The results indicate that modifying SRI components to suit farmers' preferences result in comparatively higher yields than conventional practices. Encouraging farmers to practise SRI in their own way could be beneficial, instead of forcing them to follow a defined method. This way, modified SRI or improved management practices would enhance the rice yield compared to older practices.

(3) SRI hot spots/regions: The focus must be on locations with suitable soils, crop seasons (kharif/rabi), and irrigation sources (surface/groundwater/rainfed). Using GIS mapping, areas suitable for SRI (hot spots) can be marked and attention can be paid to popularising the practice in these regions.

(4) Machine transplantation: Scarcity of labour comes in the way of SRI practices that need timely attention. Machine transplanting can be introduced in all regions using wider spacing, young seedlings, and one to two seedlings. The success of machine transplanting in locations like the Krishna and Godavari basins needs to be replicated under SRI. Further, given the labour cost and difficulty in operating manual cono-weeders, power cono-weeders could be considered.

(5) Capacity-building programmes: Imparting training to farmers on the SRI components that are important to their region is essential. This will make them more confident in carrying out follow-up tasks. Making user-friendly cono-weeders available at a lower cost will persuade farmers to use them in their fields.

(6) Long-term field experimentation: As yields vary across regions as well as with different soils and irrigation sources, long-term field experimentation with different SRI practices is important so that concrete conclusions can be drawn about their sustainability.

(7) The Twelfth Five-Year Plan approach paper highlights the importance of SRI practices in improving crop productivity (GOI 2011). The drivers of SRI adoption can be examined and incorporated in agricultural development programmes such as the Rashtriya Krishi Vikas Yojana.

NOTES

1 Out of 2,234 sample farmers, 1,948 were SRI farmers and 286 were non-SRI farmers. Besides, most of the SRI farmers also had non-SRI fields, and these were also taken for comparison of SRI and non-SRI yields. The sample size in the eastern, central and western states was comparatively low as the total number of SRI farmers was low in the selected districts. The study mainly analysed the current SRI performance (in terms of level of adoption of SRI components and corresponding yield levels) and not the extent of adoption of SRI in different states.

2 Even though water use under SRI is said to be less, this is not covered in this study as most of the farmers did not have the perfect land level to facilitate water-saving irrigation.

3 In general, most of the regions reported that the cost reduction was due to a reduced seed rate (less than 5 kg/ha) under SRI/modified SRI compared to about 75kg/ha under conventional practice. Also, cono-weeders reduced the use of labourers for weeding, even though not all used cono-weeders. The number and duration of irrigations under SRI/modified SRI was also comparatively less.

4 To keep the discussion straight, region-wise comparisons are given even though detailed analyses were done at the state and regional levels.

5 The low adopters incurred about Rs 390/ha as additional cost to follow SRI practices; partial adopters incurred about Rs 520/ha, and full adopters incurred about Rs 650/ha.

6 The transaction cost was on the lower side, as the opportunity cost of farmers' time and effort in making labourers to do the transplanting and cono-weeding varied across locations. Farmers also felt that transplanting single seedlings resulted in poor growth in waterlogged fields. Many farmers felt it was not necessarily the cost but the "serious efforts" made to mobilise resources in time for SRI/modified SRI practices that mattered.

7 Current rice production in the country is about 89 million tonnes, and the eastern region accounts for 36 million tonnes, followed by the southern region (20.5 million tonnes). Though current rice productivity in the eastern region (with 18.8 million ha under rice) is about 1.9 tonnes/ha compared to 2.9 tonnes/ha in the southern region (with 7 million ha under rice), the additional yield due to SRI/modified SRI will be more or less the same in both regions. The issue of farmers giving up on SRI should be carefully addressed so that they realise they can do SRI differently and need not revert to conventional practices.

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Appendix 1

Multinomial Logit Model for Estimation of Factors Influencing SRI Adoption

SRI adoption is considered a combination of a set of technologies. The level of adoption of the core components decides the level of adoption of SRI. The low or non-adopter is one who does not follow any of the core components, against the full adopter who follows all the core components. The partial adopter is one who deviates from the core component technologies. Though the yield increase in moving from partial to full adoption is relatively less, an identification of the drivers of partial and full adoption would help in promoting SRI practices in any region. Identifying the drivers at different levels needs a special model that has the ability to handle more than one dependent variable. A multinomial logit regression model facilitates estimating the relative importance of a set of independent factors (farm and region-oriented variables) on a set of dependent variables (low, partial, and full adopters) keeping the last category/genotypes as a check or base category. The results are interpreted in comparison to the base category. The biotic and abiotic factors influencing the varietal selection process are captured through multivariate logit equations to handle more than one independent variable.

The Multinomial Distribution

Consider a random variable yi that may take one of several discrete values, which we index 1, 2…,J.
$y_i = (y_{i1}, y_{i2}, ..., y_{ir})^T$ has a multinomial distribution with index $n_i \Sigma^r_j = 1 y_{ij}$ and the parameter $\pi_i = (\pi_{i1}, \pi_{i2}, ..., \pi_{ir})^T$ when the response categories 1,2,…, r are unordered. The most popular way to relate π_i to covariates is through a set of r-1 baseline-category logit. Taking j^* as the baseline category, the model is $\left(\frac{\pi_{ij}}{\pi_{ij^*}}\right) = x_i^T \beta_j,\ j \neq j^*$.

If x_i has length p, then this model has (r-i) × p free parameters, which we can arrange as a matrix or a vector. For example, if the last category is the baseline ($j^* = r$), the coefficients are

$$\beta = [\beta_1, \beta_2, ..., \beta_{r-1}] \text{ or vec } (\beta) = \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_{r-1} \end{bmatrix}$$

- The k^{th} element of β_i, can be interpreted as the increase in log odds of falling into category j versus category j^* resulting from a one unit increase in the k^{th} covariate, holding the other covariates constant.
- The estimated coefficients vary between plus and minus infinity. A coefficient of 0 indicating the given explanatory variable does not affect the logit, i e, the coefficient increases the explanatory variable increase or decreases the logit of the dependent. The *exp(b)* is the odd ratio-OR; when *b=0; exp (b)=1*, which means that the corresponding explanatory variable does not affect the dependent variable. For the continuous variable, the odd ratio represents the factor by which the *odd* (event) change for a one unit changes in the variable. That is, the *odd ratio (OR)* is the ratio of *odds* for two groups where each group value of x_j.
- If *OR>1,* it means the independent variable increases the logit and therefore increases the odd. If *OR=1,* the independent variable has no effect. If *OR<1,* the independent variable decreases the logit and decreases the odd (event).

Appendix 2
Test of Significance of Variables

The t-test results on farm size categories confirmed that there is no significant difference in SRI yield, particularly between small and large farms. However, these farms had significantly different yields over marginal farms in the southern and western regions.

Zone	Group (1, 2)		Group (1, 3)		Group (2, 3)	
	t value	Sign	t value	Sign	t value	Sign
SI	-6.269	***	-6.652	***	-0.846	Ns
WI	-2.040	**	-1.725	**	0.364	Ns
EI	-2.891	**	-1.445	Ns	0.141	Ns
CI	-0.824	Ns	0.945	Ns	1.048	Ns
NE	-1.444	Ns	-1.547	Ns	-1.022	Ns
AL	-9.672	***	-12.333	***	-3.521	***

Groups 1, 2 and 3 represent marginal, small and large farm sizes respectively.

The t-test results on SRI yields under different sources of irrigation confirmed that there is significant yield difference between groundwater and conjunctive irrigation systems over rainfed SRI, but there is no significant yield difference between surface and conjunctive irrigation. This confirmed that groundwater and conjunctive irrigation had a positive influence on SRI yield.

Zone	Group (1,2)		Group (1, 3)		Group (1, 4)		Group (2, 3)		Group (2, 4)		Group (3, 4)	
	t value	Sign	t value	Sign	t value	Sign	t value	Sign	t value	Sign	t value	Sign
SI	-2.560	**	0.129	Ns	2.264	ns	4.238	***	2.388	Ns	2.286	**
WI	2.537	***	0.221	Ns	0.432	ns	-1.453	ns	-2.104	Ns	-0.508	ns
EI	6.522	ns	0.015	Ns	2.916	***	1.154	ns	7.680	Ns	4.099	***
CI	-0.309				-2.464	**			1.661	Ns		
NE		ns					0.340	ns	3.855	***	3.842	***
AL	-2.152		0.373	Ns	13.521	***	1.180	ns	15.488	***	15.132	***

Groups 1, 2, 3 and 4 are for surface, ground, conjunctive and rainfed water supply respectively.

The t-test result on SRI yield under different soil types revealed that clay loam has a significant positive yield advantage over clay and black soil. Black soil has significantly less yield over clay, clay loam, red and sandy loam soil.

Zone	Group (1, 2) t value	Group (1, 3) t value	Group (1, 4) t value	Group (1, 5) t value	Group (2, 3) t value	Group (2,4) t value	Group (2, 5) t value	Group (3, 4) t value	Group (3, 5) t value	Group (4, 5) t value
SI	11.450	6.058	6.838	7.054	-4.375	-1.001	-5.223	2.124	0.033	-2.530
WI		-5.606	-2.171					2.132		
EI		-0.821		5.054					8.402	
CI		-4.816	-2.349	-5.889				3.583	-3.872	-5.117
NE										
AL	-9.713	-2.946	-3.477	-4.587	7.814	4.943	10.419	-1.527	-0.752	1.529

Groups 1, 2, 3, 4 and 5 are for black, clay, clay loam, red and sandy loam soil respectively.